BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B69 06098

SUBJECT: Screening of Line of Sight to LM by Craters at Apollo Site 2 - Mission G
Case 320

DATE: June 30, 1969

FROM: I. I. Rosenblum

ABSTRACT

Difficulties arise in attempting to provide continuous communications coverage between the LM and a roving receiver on proposed advanced lunar missions where traverses out to a 5 km radius may occur. Part of the coverage problem is associated with direct screening of the line of sight by crater rims and other terrain features. Specific crater parameters given by available topographical map data for Site 2 provide the basis for estimating shadowing effects by crater rims out to a radius of 5 km, for several combinations of LM and ROVER antenna heights, (the highest values used are 500 feet for LM and 50 feet for ROVER). Single knife-edge and double knife-edge diffraction (after WILKERSON 1966) is the method used for approximating the signal loss with respect to free space in the shadow areas both inside the site craters and beyond the crater rims. Results indicate that a significant screening problem exists at 300 MHz.

(NASA-CR-106745) SCREENING OF LINE OF SIGHT TO LM BY CRATERS AT APOLLO SITE 2 - MISSION G (Bellcomm, Inc.) 20 p

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MEMORANDUM FOR FILE

I. INTRODUCTION

In order to gain a better understanding of the influence of terrain features on communication between LM and a roving receiver on the lunar surface for advanced lunar exploration, an investigation was made of the predicted shadow areas at Site 2 (G Mission). This site was chosen because detailed topographical data are available and because this site, by having numerous and varied sized craters within a 5 km radius, will perhaps suggest the relative magnitude of the communication problems over the terrain of the more advanced mission sites (for which detailed topographical data are not yet available).

II. ANALYSIS

The significant craters within a 5 km radius of the proposed LM landing site were identified from map data in Reference 1 (which gives rim height and crater depth), part of which is reproduced as Figure 1. Estimates of crater diameters and distances from the proposed LM landing site were determined from scale measurements of topographical map data or from Lunar Orbitor photographs, and are given in Table 1.

Screening of the line of sight was evaluated for the following combinations of LM antenna height and rover receiver antenna height:

	ROVER ANTENNA HEIGHT(ft)		
LM ANTENNA HEIGHT(ft)	6	25	50
25	X	X	X
100	X	X	X
500	X	X	X

In this investigation it was desired to find the areas within the 5 km radius which would be shadowed by crater rims for these antenna heights and roughly to quantize the communication loss in the shadowed region.

The evaluation of the shadow area was accomplished by resorting to plane surface geometry and by representing the crater rims as perfectly absorbing knife-edge diffraction lines. EPSTEIN and PETERSON reported (in Reference 2) useful agreement between experimental data (at 850 MHz) and theoretical predictions based on the knife-edge theory, for the shadow region behind hills even though ordinary hills are anything but knife edges. Crater rims would thus equally appear to be appropriately represented as knife-edges. WILKERSON (in Ref. 3) has shown that for the double knife-edge diffraction case, the attenuation coefficients can be satisfactorily determined (usual error of 1 or 2 db) by using the EPSTEIN and PETERSON approximation. In this method it is assumed that the total attenuation is the product of the attenuations at each ridge top due to the other ridge. Referring to Figure 2, the attenuations are associated with ray paths TP1 P2 and P1 P2 R respectively. The attenuation is given by:

$$A2,\ EP = F1\ (B1)\ F2\ (B2) \qquad (1.1)$$

where B1 and B2 are given in equation (1.4) of Reference 3. In Reference 3, part 2, WILKERSON discusses and gives a straightforward expression for numerically determining values of B1 and B2 in the following form:

$$B1,\ 2 = 2.583\ \Theta 1,\ 2\ [f \cdot r_1 r_2/(r_1+r_2)]^{1/2} \qquad (1.2)$$

where f = frequency in MHz

and where, referring to Figure 3,

- Θ1 and Θ2 are the diffraction angle tangents (equal to the angle for small Θ), determined from the geometry
- r1, r2, and r3 are the separation distances in kilometers, and
- H1, H2, and H9 are the heights of the LM antenna, crater rim and rover antenna respectively.

As a simplification to the investigation, an alternate form of the above expression (1.2) was used to obtain B1 (and B2) namely:

$$B1 = .707\ \Theta 1\ [\pi(r_1\ r_2)/\lambda(r_1+r_2)]^{1/2} \qquad (1.3)$$

where all lengths are in meters and λ = the wavelength.

Since only approximate data was being sought, the values of B1, B2 were equated with the dimensionless parameter v, and numerical values for F1 (B1), F1 (B2) were approximated, based on the attenuation curve for v given in Figure 3 of Reference 3, by:

$$F1,\ 2\ (db) = 6\ db + 6.95\ (B1,2) \qquad (1.4)$$

from the 6 db point to the 12.95 db point and above 12.95 db by:

$$F1,\ 2\ (db) = 12.95\ db + 20\ \log\ (B1,\ 2) \qquad (1.5)$$

For the cases where the LM antenna height exceeded the crater rim height, single knife-edge diffraction over the far crater rim was evaluated and for the cases where rover antenna height exceeded crater rim height (LM antenna lower than crater rim) single knife-edge diffraction over the near crater rim was taken.

A communication frequency of 300 MHz was used for this investigation as an approximation to the LM voice frequencies of 296.8 MHz and 259.7 MHz.

III. RESULTS

A. Screening Beyond Crater Rims

Calculations were made of the diffraction loss relative to free space for each of 20 specific craters within 5 km of the proposed LM landing point for Site 2. Diagrams showing the shadowing created by these craters are given in Figures 4 through 12, each of which shows two (2) shadings representing two (2) gross levels of shadow loss. These figures provide direct indication of the extent to which terrain features at a site can inhibit communication; they show the approximate point of 12db attenuation and, where applicable, the line of sight distance, defined as the distance at which the signal path just grazes the intervening terrain, which is marked as the 6db point. The unshaded areas within the radial lines represent loss areas of less than 6db.

As can be seen, even with the very substantial LM antenna height of 153 meters, significant areas within the 5 km radius are screened by crater rims.

B. Screening Inside Crater Rims

Screening within Site 2 craters was evaluated using single knife-edge diffraction over the near rim to a receiving point located at the near slope, S1, the crater bottom, B, or the far slope, S2. (see Figure 13). For this evaluation the slope angle was assumed to be 35°. The results for the most favorable antenna combination examined (LM = 153M, ROVER = 15.2M), are given in Table 2 which shows:

1. The loss at the bottom of S1 where attenuation is greatest.

2. The loss at the crater center (bottom).

3. The distance, r6, at which the theoretical loss is about 12db (generally part way up S2).

As seen from the values of r6 compared to the crater diameters, r2, a high percentage of the area of each crater suffers a signal loss of 12db or greater, with the exception of a small and nearby crater (#13 in the Table). The average attenuation at the crater center for all craters is approximately 26db.

If the extended range communication system is designed to provide a free space field that is just adequate at 5 km, then a signal margin will exist at shorter ranges as follows:

5KM	0 db
4KM	2
3KM	4.4
2.5KM	6
2	8
1.5	10.4
1	14
.7	17
.5	20

Of the 20 craters associated with Site 2, only one is sufficiently close (distance of 700M) so that the signal margin arising from its proximity is sufficient to overcome the calculated diffraction losses at the crater floor, for the case where LM antenna is elevated to 153 meters and ROVER or EVA antenna is elevated to 15.2 meters. (See Table 2)

For the unelevated antenna case, i.e., with LM at 7.6 meters and EVA at 1.8 meters, communication to even this shallow and modestly rimmed crater (D2-27M, H2-14M) disappears as the losses increase to about 25db at the crater floor. The average attenuation at the crater center for all 20 craters, with this antenna combination is about 30db.

IV. CONCLUSIONS

From this investigation it is concluded that:

a) Line of sight screening problems to LM will exist in the areas behind hills and the rims of craters of modest rim heights (14-90 meters), even for considerable extended antenna heights.

b) The bottoms of craters represent a particularly difficult area in which to maintain communications directly between LM and a roving receiver as evidenced by typical losses of 25-30 db at 300 MHz.

c) Maintaining continuous communications to LM on advanced lunar exploration missions appears to require more drastic measures than just increased antenna heights; relay devices to LM, a direct ROVER-to-EARTH link, and frequencies in HF band, among other solutions, should be investigated further.

2034-IIR-mbr

I. I. Rosenblum

REFERENCES

1. Lunar Map ORB-II-6 (100) 1st Edition, Dec., 1967, Army Map Service, Corps of Engineers, U. S. Army for NASA.

2. Epstein, J. and D. W. Peterson (1953), "An Experimental Study of Wave Propogation at 850 MC", Proc. IRE 41, No. 5, 595-611.

3. Wilkerson, R. E. (1966), "Approximations To the Double Knife-Edge Attenuation Coefficient", Radio Science, Vol. 1, No. 12, Dec., 1966.

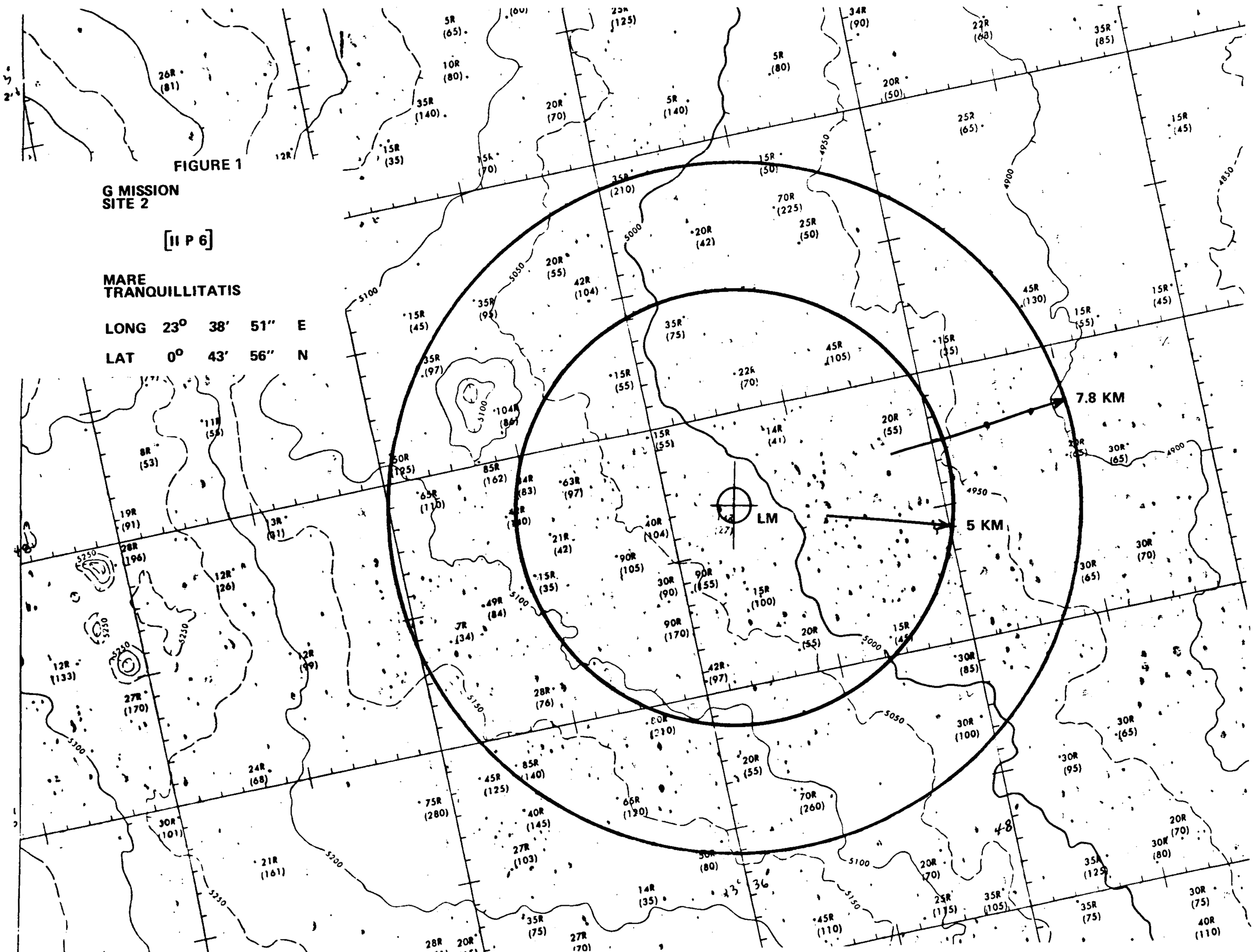


FIGURE 1

G MISSION
SITE 2

[II P 6]

MARE
TRANQUILLITATIS

LONG 23° 38′ 51″ E

LAT 0° 43′ 56″ N

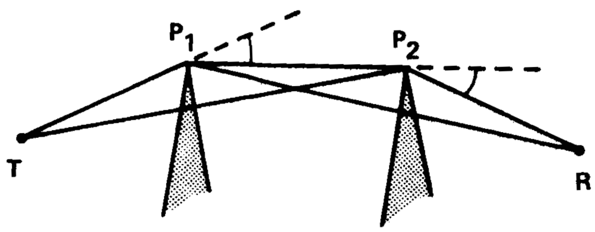
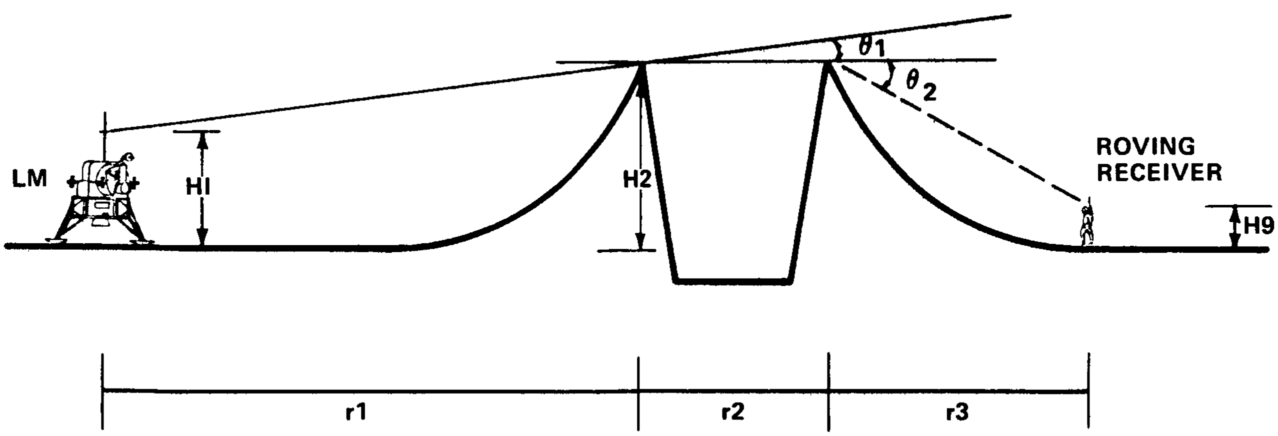


FIGURE 2 - THE EP (EPSTEIN-PETERSON)
APPROXIMATION.

FIGURE 3 - GEOMETRY FOR DOUBLE KNIFE-EDGE DIFFRACTION OVER CRATER RIMS



LM ANT. HT	7.6 METERS (25 ft)
ROVER ANT. HT	1.8 METERS (6 ft)

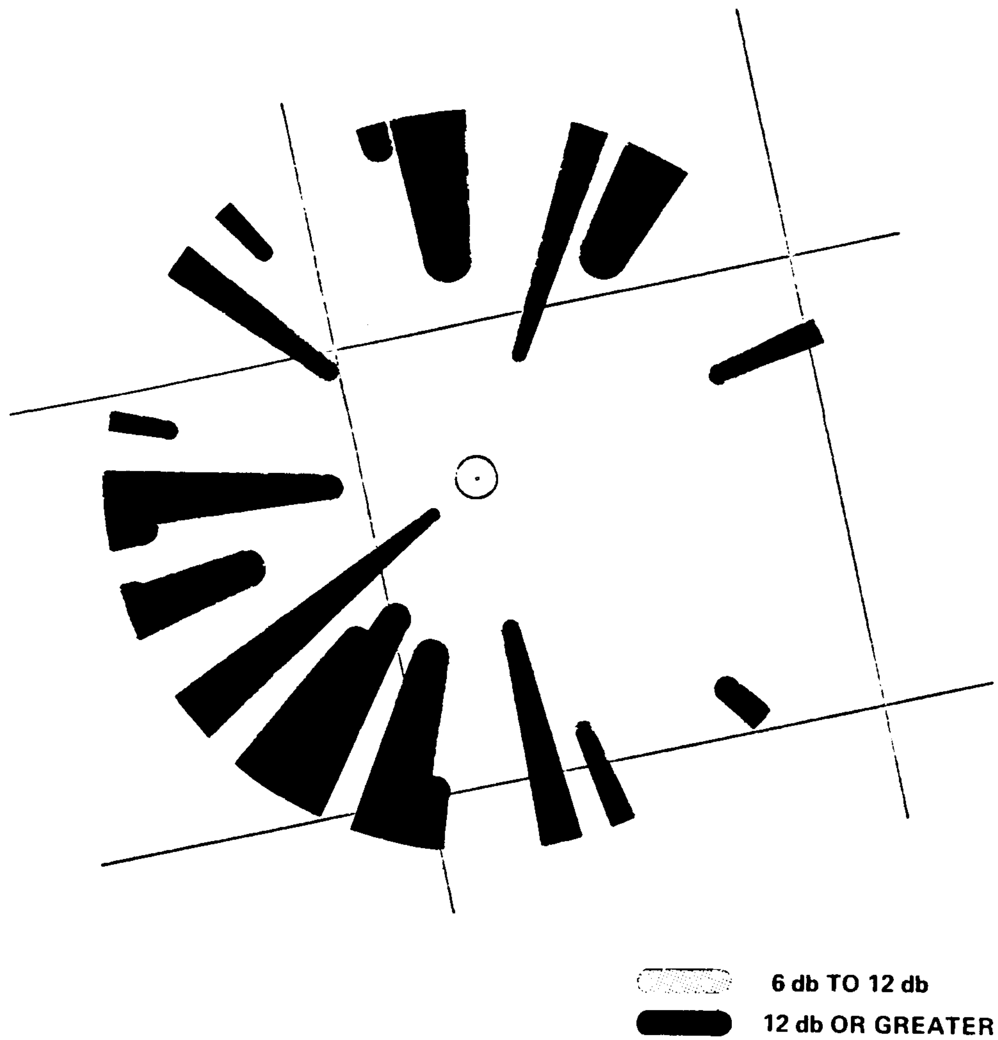


FIGURE 4 - SCREENING OF LINE OF SIGHT TO LM BY SITE 2 CRATERS

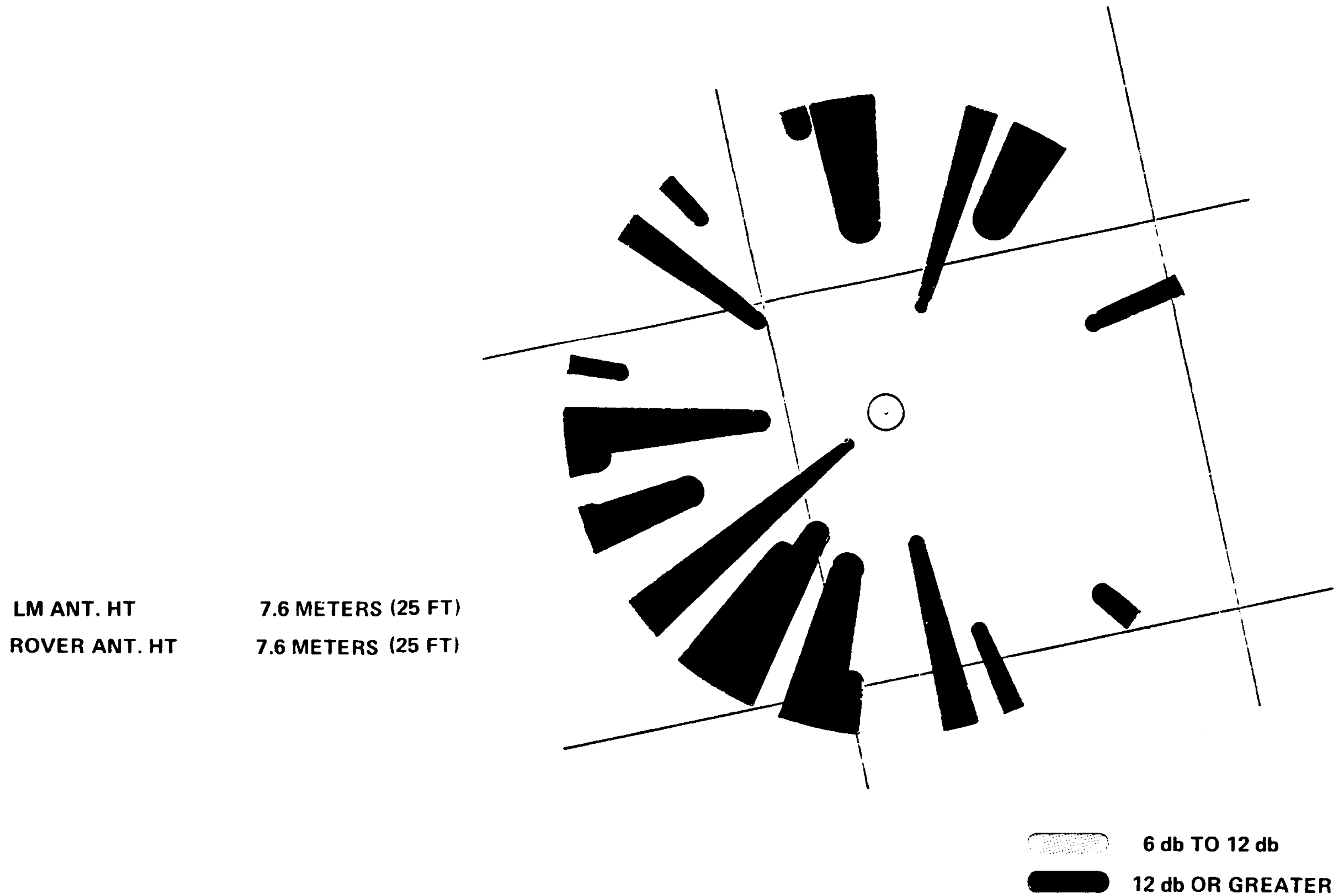
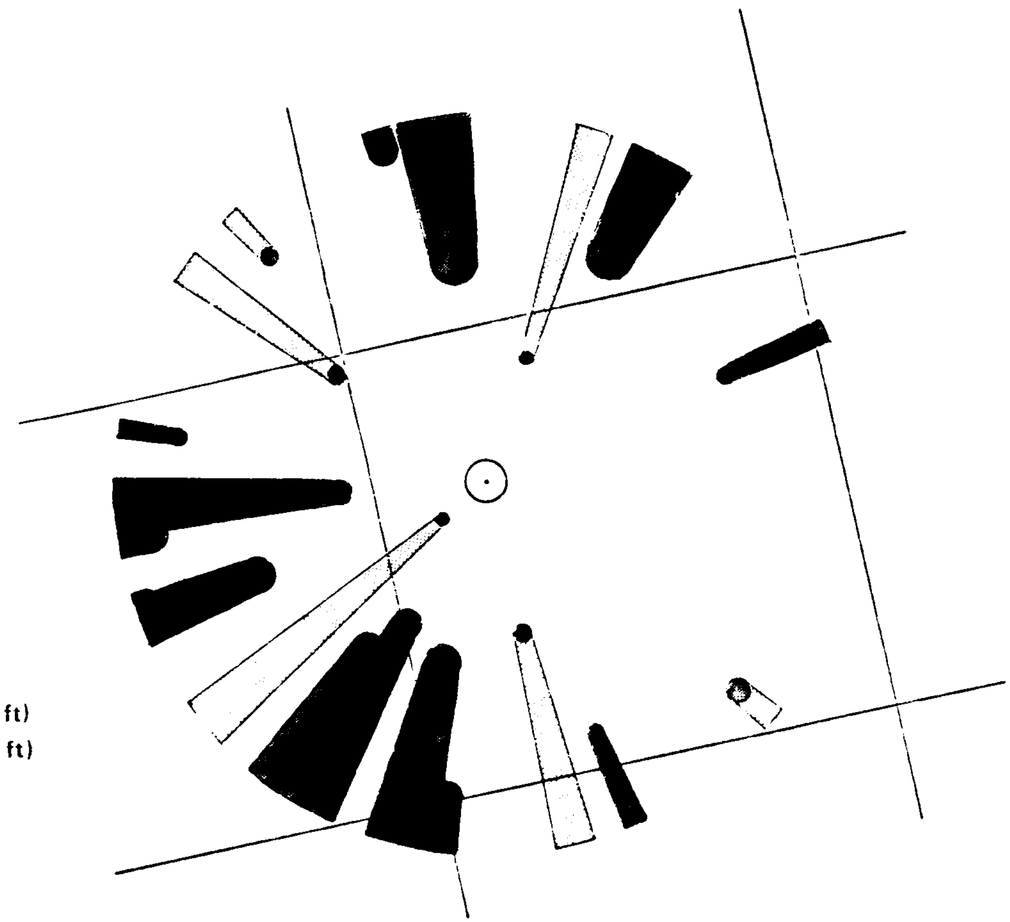


FIGURE 5 - SCREENING OF LINE OF SIGHT TO LM BY SITE 2 CRATERS

LM ANT. HT	7.6 METERS (25 ft)
ROVER ANT. HT	15.2 METERS (50 ft)



6 db TO 12 db

12 db OR GREATER

FIGURE 6 - SCREENING OF LINE OF SIGHT TO LM BY SITE 2 CRATERS

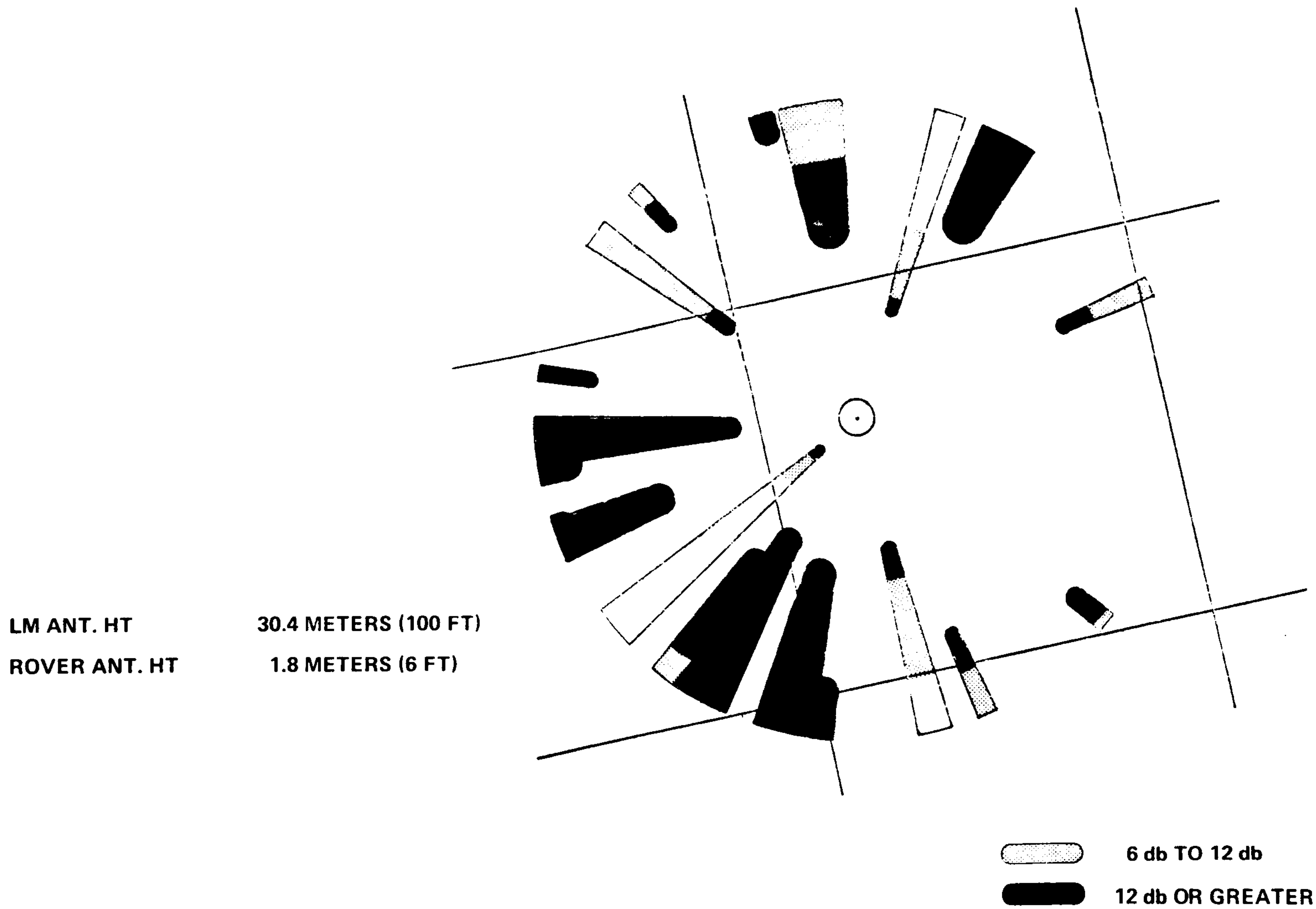


FIGURE 7 - SCREENING OF LINE OF SIGHT TO LM BY SITE 2 CRATERS

LM ANT. HT	30.4 METERS (100 FT)
ROVER ANT. HT	7.6 METERS (25 FT)

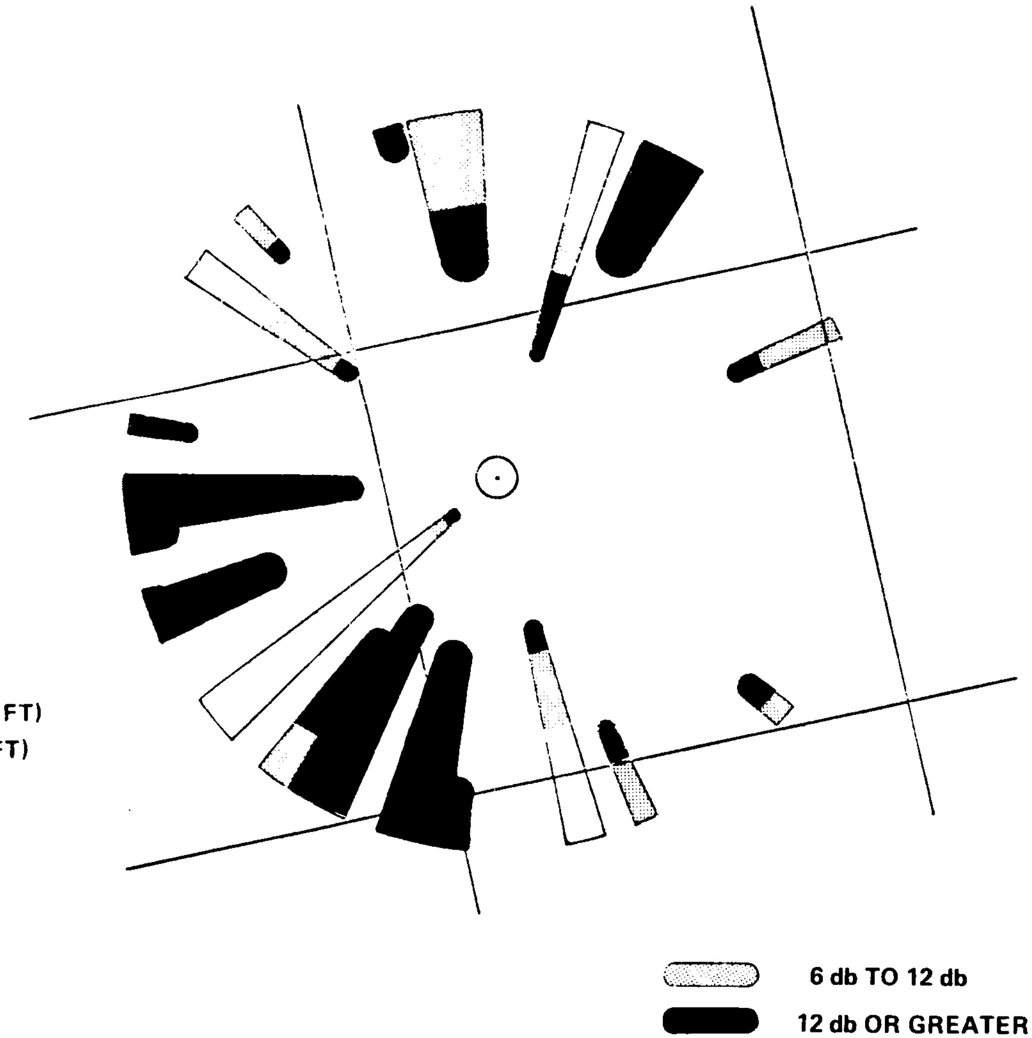


FIGURE 8 - SCREENING OF LINE OF SIGHT TO LM BY SITE 2 CRATERS

LM ANT. HT 30.4 METERS (100 FT)
ROVER ANT. HT 15.2 METERS (50 FT)

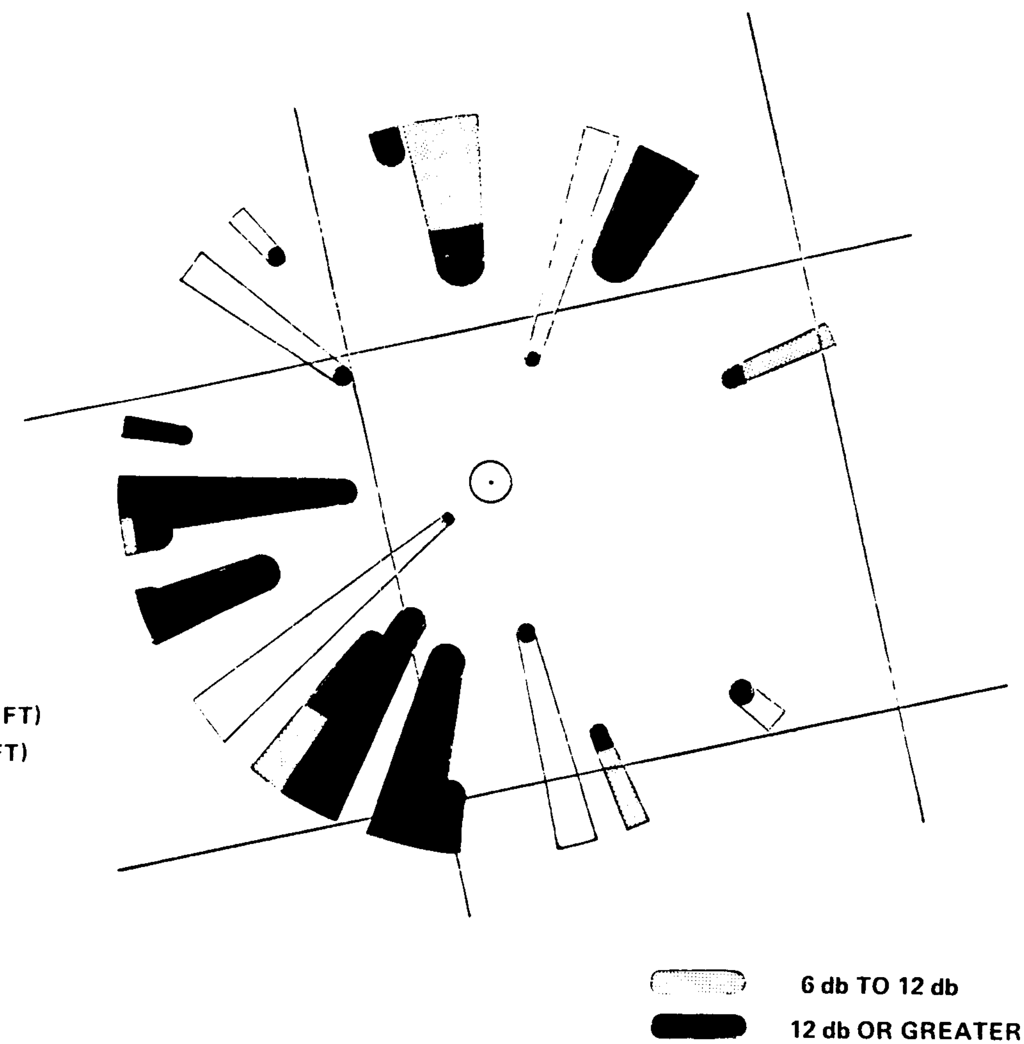


FIGURE 9 - SCREENING OF LINE OF SIGHT TO LM BY SITE 2 CRATERS

LM ANT. HT	153 METERS (500 FT)
ROVER ANT. HT	1.8 METERS (6 FT)

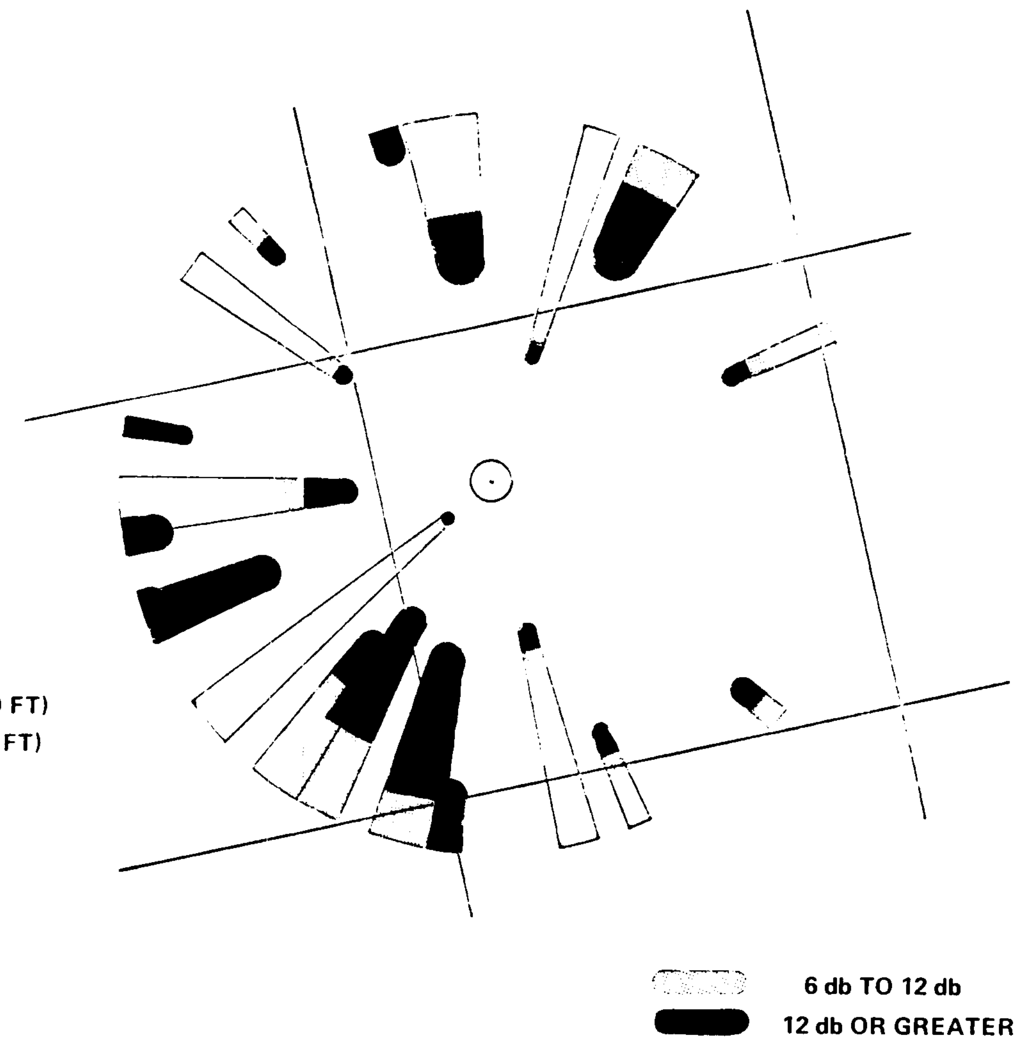


FIGURE 10 - SCREENING OF LINE OF SIGHT TO LM BY SITE 2 CRATERS

LM ANT. HT 153 METERS (500 FT)
ROVER ANT. HT 7.6 METERS (25 FT)

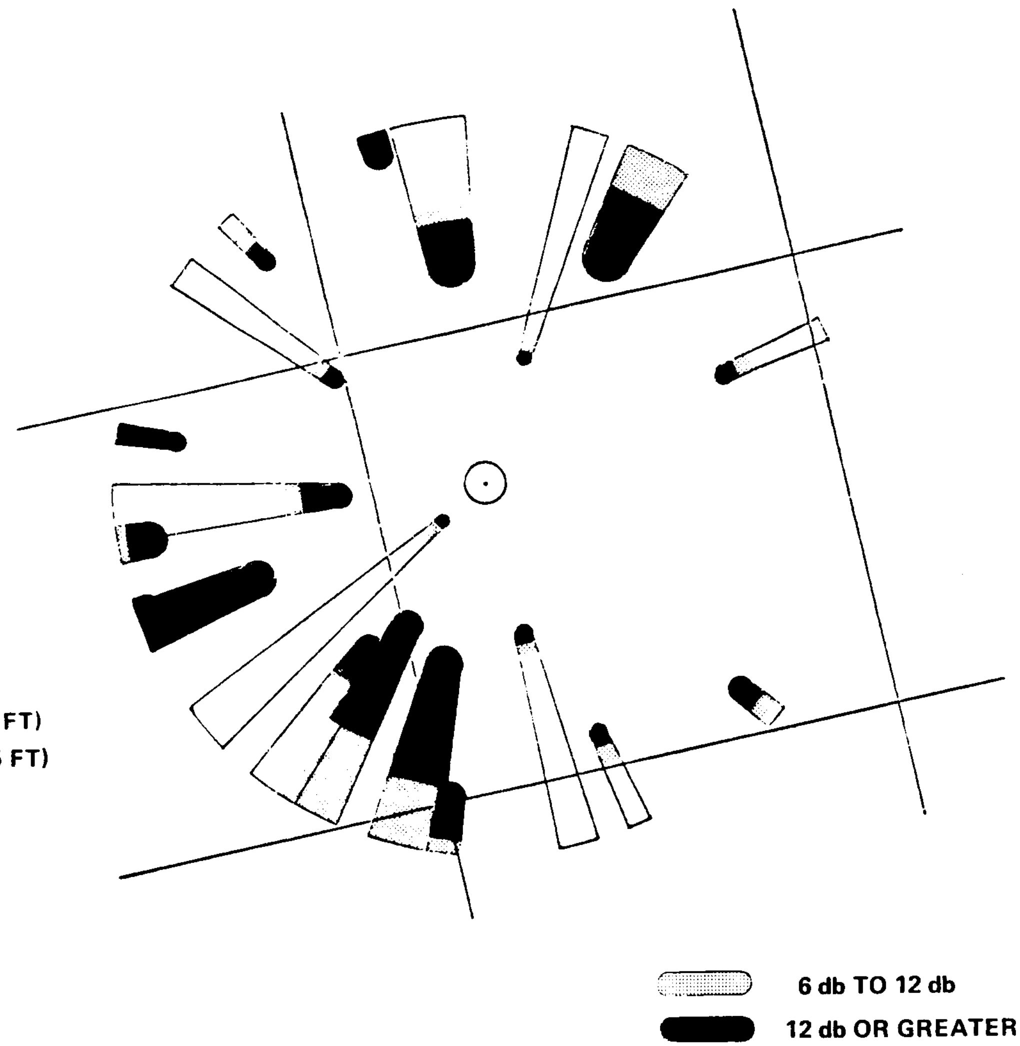


FIGURE 11 - SCREENING OF LINE OF SIGHT TO LM BY SITE 2 CRATERS

LM ANT. HT	153 METERS (500 FT)
ROVER ANT. HT	15.2 METERS (50 FT)

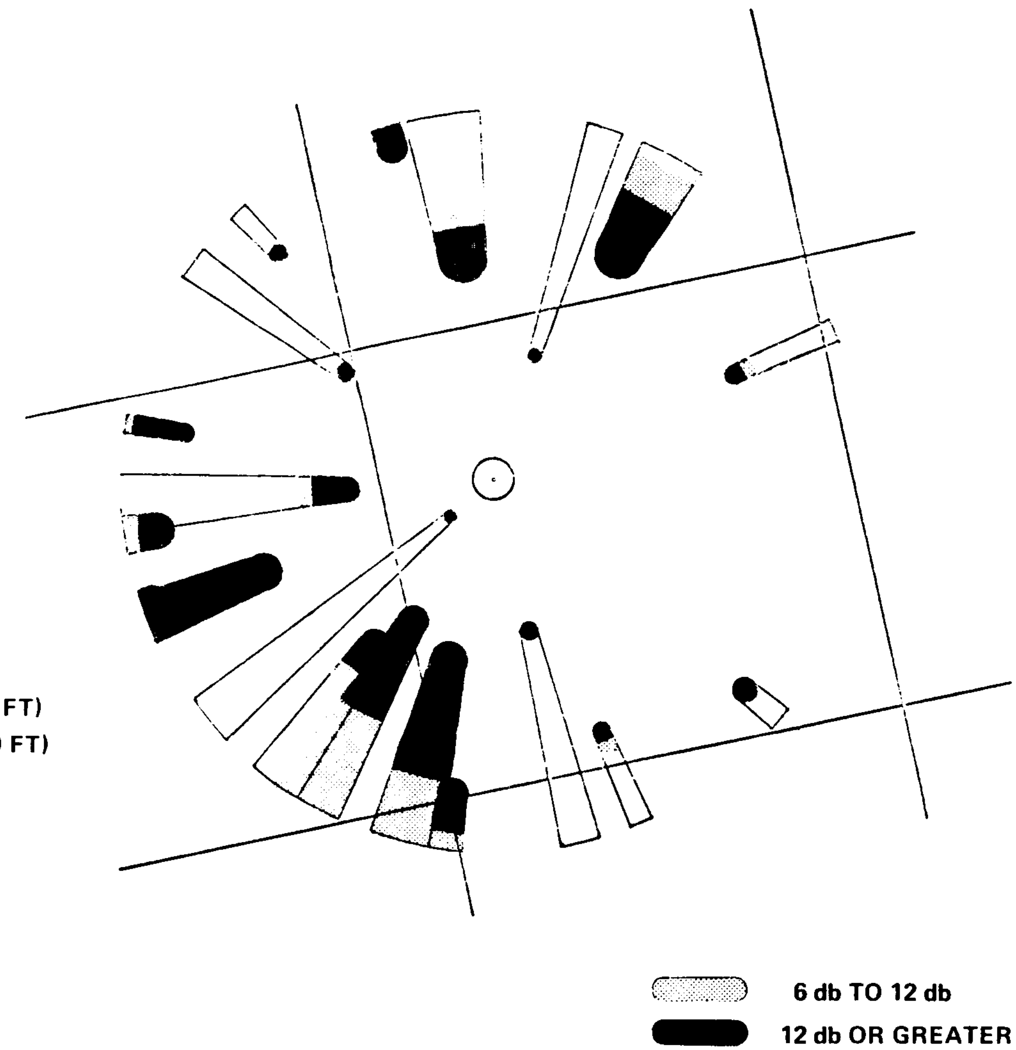


FIGURE 12 - SCREENING OF LINE OF SIGHT TO LM BY SITE 2 CRATERS

FIGURE 13 - GEOMETRY FOR SINGLE KNIFE-EDGE DIFFRACTION TO POINTS INSIDE CRATER

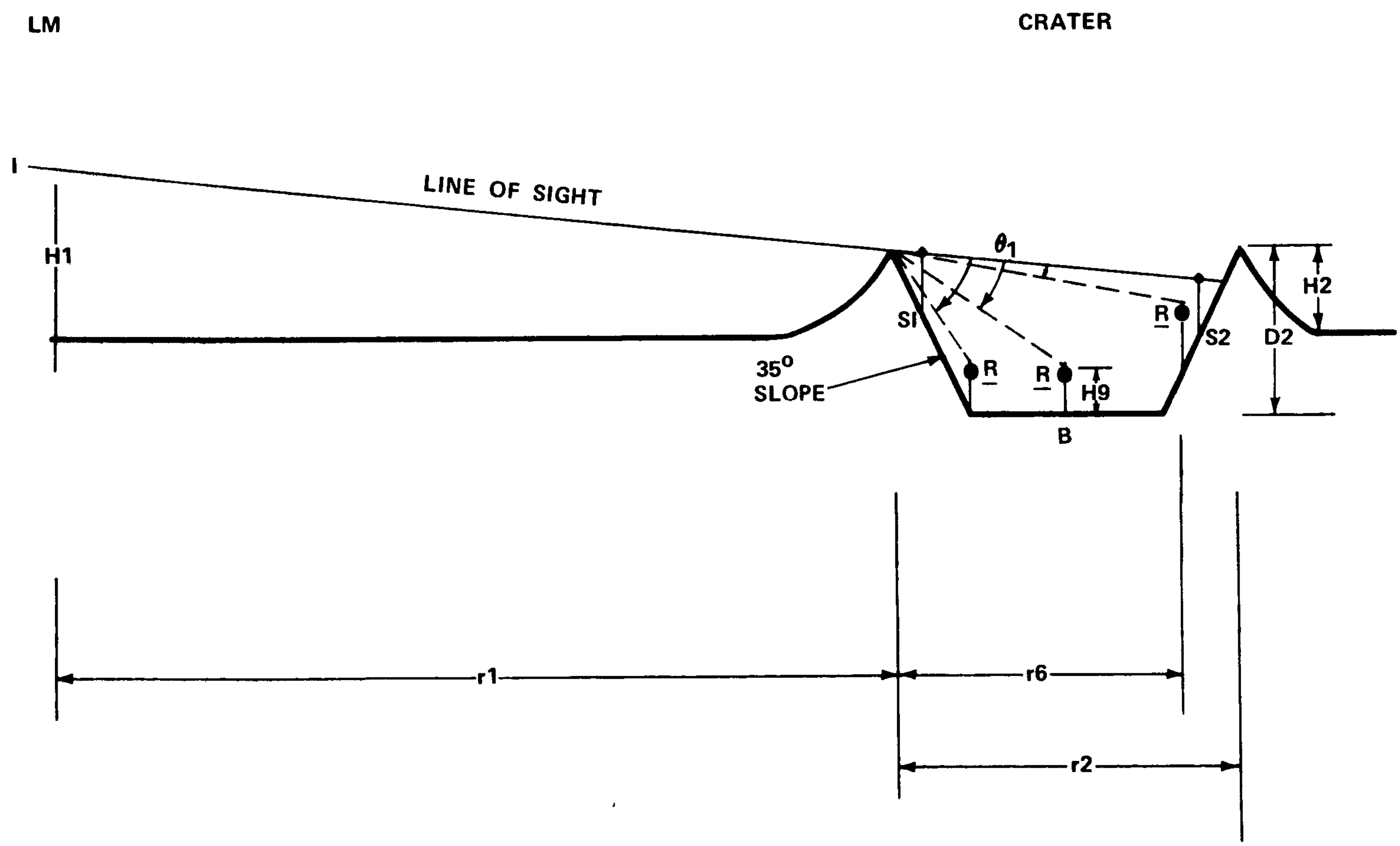


TABLE 1 - MISSION G-SITE 2 CRATERS WITHIN 5 KILOMETERS OF LM

CRATER NO.	RIM HEIGHT (H_2)	CRATER DIAMETER (r_2)	DISTANCE TO LM (r_1)
METERS	METERS	METERS	METERS
1	35	400	4400
2	22	600	2700
3	14	100	1700
4	45	600	3100
5	20	200	3300
6	15	300	4200
7	20	200	3500
8	15	200	2000
9	42	400	4000
10	90	500	2200
11	90	400	2000
12	30	400	2500
13	14	100	700
14	90	500	3000
15	15	300	4600
16	21	500	4200
17	40	300	1800
18	63	200	4000
19	15	200	2300
20	15	200	4000

TABLE 2 - SCREENING DATA FOR POINTS WITHIN SITE 2 CRATERS FOR LM ANT. HT = 153 M AND ROVER ANT. HT = 15.2 M

CRATER NO.	RIM HEIGHT (H_2)	CRATER DIAMETER (r_2)	LM DISTANCE (r_1)	CRATER DEPTH (D_2)	LOSS @ SI-MAX	LOSS @ BOTTOM CENTER	DISTANCE TO 12 DB (r_6)
	METERS	METERS	METERS	METERS	DB	DB	METERS
1	35	400	4400	75	30	26	350
2	22	600	2700	70	29	22	510
3	14	100	1700	41	23	22	60
4	45	600	3100	105	31	28	520
5	20	200	3300	55	27	26	160
6	15	300	4200	45	26	21	230
7	20	200	3500	55	27	26	160
8	15	200	2000	100	31	28	150
9	42	400	4000	97	31	29	350
10	90	500	2200	170	34	34	430
11	90	400	2000	155	33	33	330
12	30	400	2500	90	30	28	320
13	14	100	700	27	12	8	40
14	90	500	3000	105	32	29	420
15	15	300	4600	35	23	17	220
16	21	500	4200	42	25	16	400
17	40	300	1800	104	31	31	250
18	63	200	4000	97	31	29	160
19	15	200	2300	55	27	25	160
20	15	200	4000	55	27	26	160

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